NASA LaRC Contribution to the High Angle Working Group of the Third Aeroelastic Prediction Workshop: BSCW Shock Buffet

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FUN3D Core Capabilities

http://fun3d.larc.nasa.gov/

- Established as a research code in late 1980s; now supports numerous internal and external efforts across the speed range
- Solves 2D/3D steady and unsteady Euler and RANS equations on node-based mixed element grids for compressible and incompressible flows
- General dynamic mesh capability: any combination of rigid / overset / morphing grids, including 6-DOF effects
- Aeroelastic modeling using mode shapes, full FEM, etc.
- Constrained / multipoint adjoint-based design and mesh adaptation
- Distributed development team using agile/extreme software practices including 24/7 regression, performance testing
- Capabilities fully integrated, online documentation, training videos, tutorials
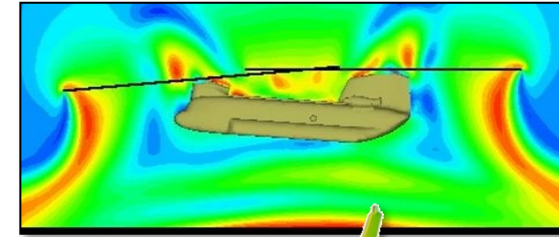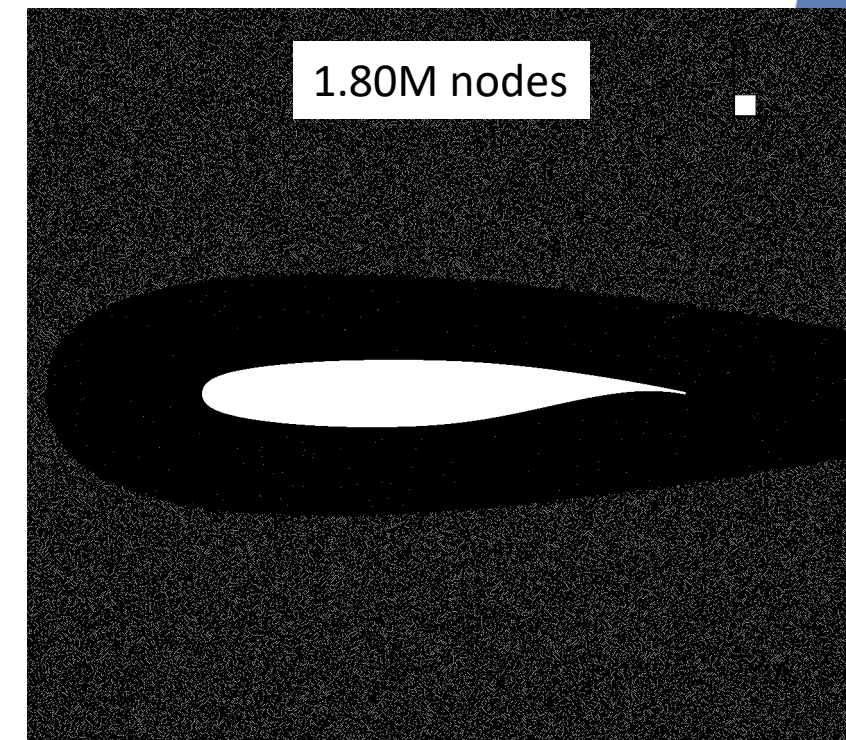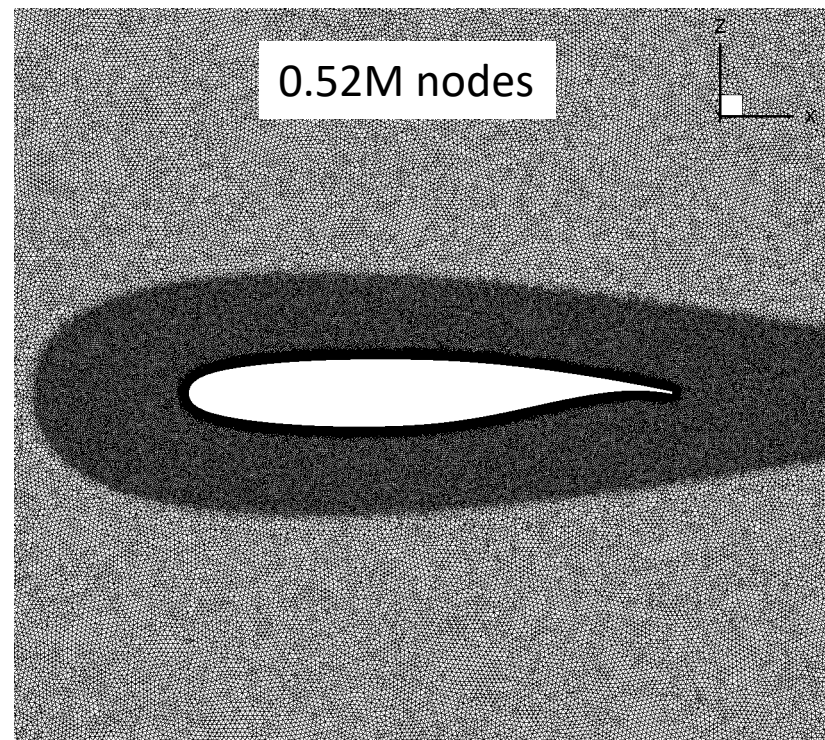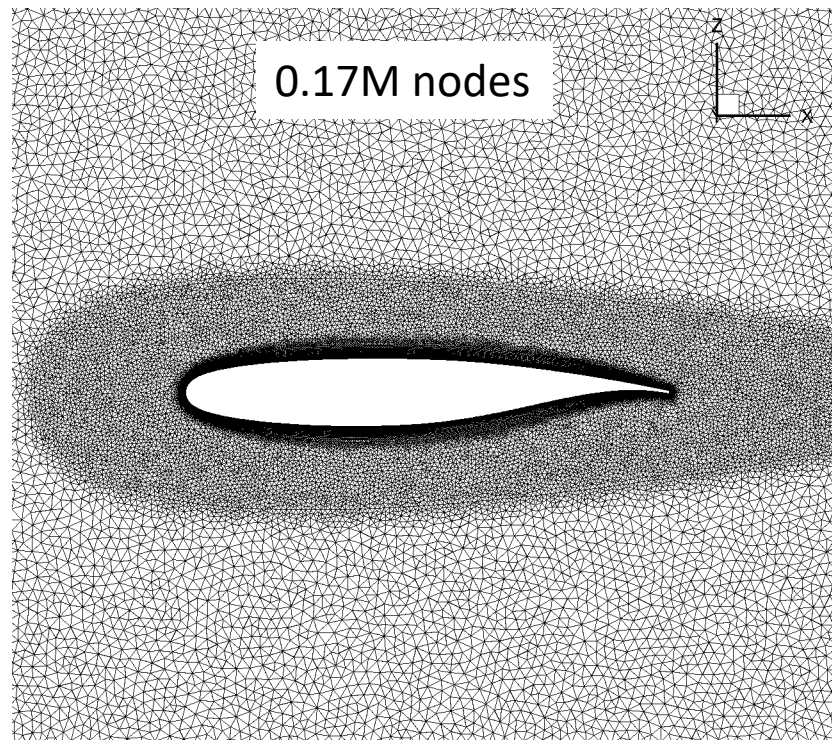
US Army
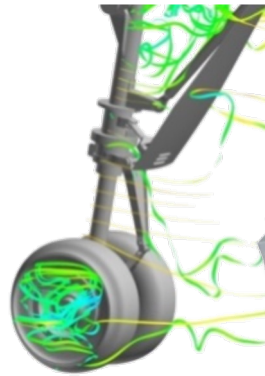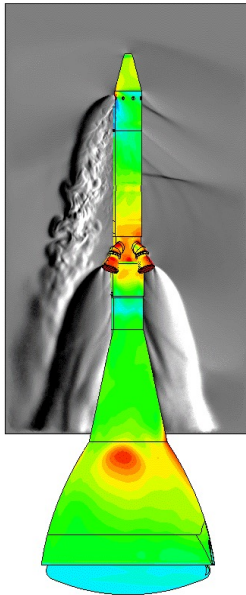
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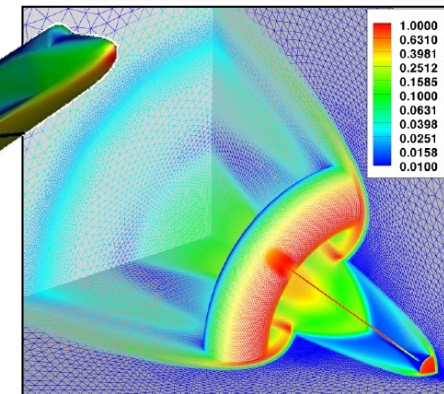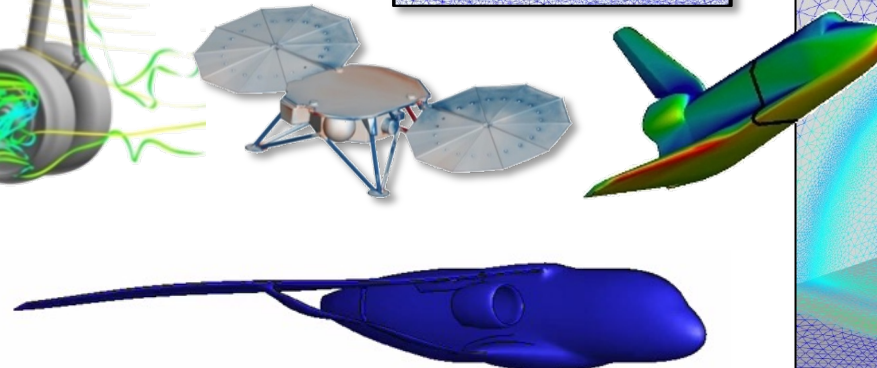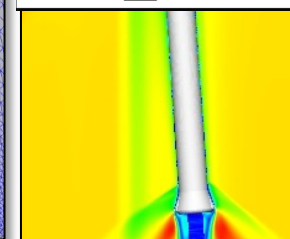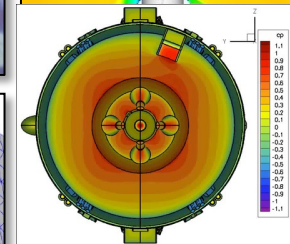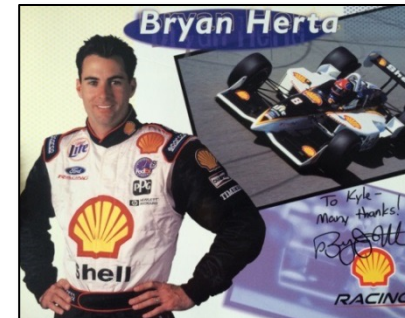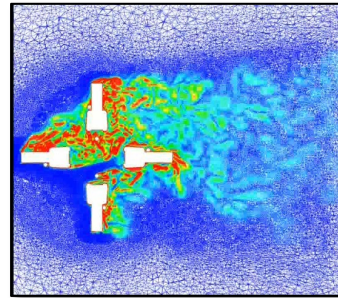
2D Analysis First !

- Meshes generated using Pointwise

- 2D implies a mesh with a unit depth of one cell in 'spanwise' direction

- Three meshes generated: Coarse, Medium, Fine

- URANS analysis with SA, SA w/compressibility correction (CC), and DDES

- Mach 0.6, 0.7, 0.74, 0.78, 0.8 with matched-point conditions from TDT's tunnel parameter code across AoAs and at Q = 170 psf !

- 2D conclusions applied to 3D coarse BSCW mesh currently used in AePW-3 analysis

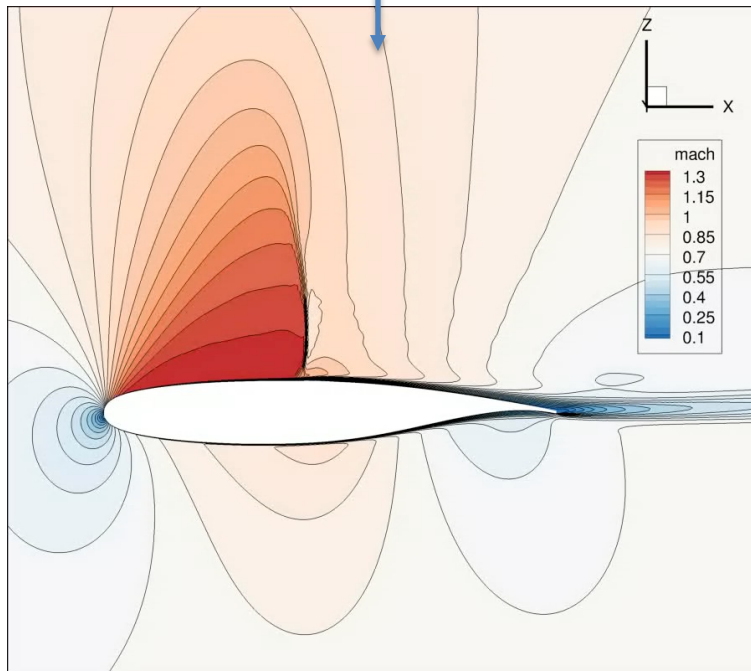## Three meshes generated: Coarse, Medium, Fine

0.17M nodes

0.52M nodes

1.80M nodes

SA + Compressibility Correction + Limiter

Medium Mesh, dt = 0.00002 sec, 160 steps/chord

| AoA (deg.) / Mach	0.60	0.70	0.74	0.78	0.80
4	N	N	Y	N	N
5	N	Y	Y	N	N
6	N	Y	Y	N	

N – Steady Flow

Y – Fluctuations in C_L

N – Initial fluctuations in C_L
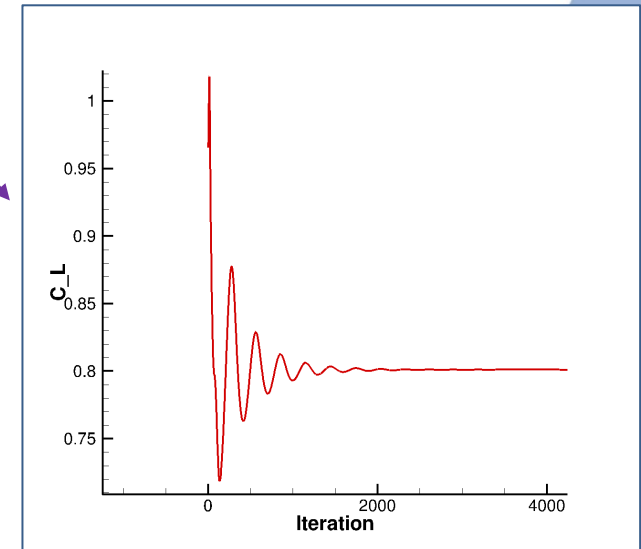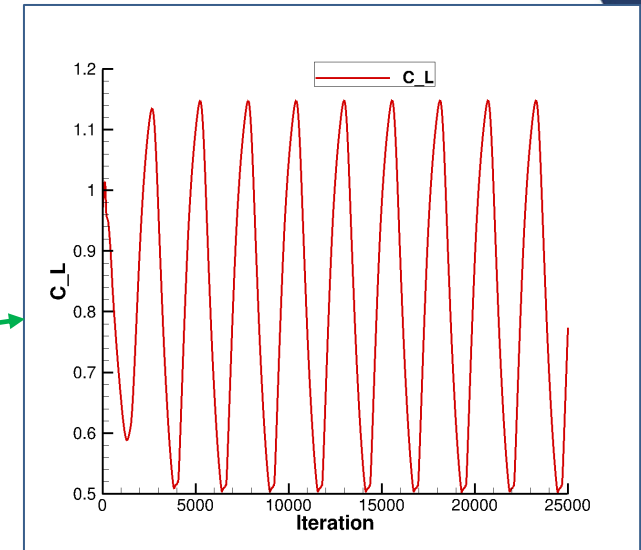
2D Analysis First !

- Meshes generated using Pointwise
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- Three meshes generated: Coarse, Medium, Fine
- URANS analysis with SA, SA w/compressibility correction (CC), and DDES
- Mach 0.6, 0.7, 0.74, 0.78, 0.8 with matched-point conditions from TDT's tunnel parameter code across AoAs and at Q = 169 psf !
- 2D conclusions applied to 3D coarse BSCW mesh currently used in AePW-3 analysis

3D Analysis Next !

- URANS with SA w/compressibility correction did not produce sufficient flow oscillations !
- 3D computations are accomplished with DDES !
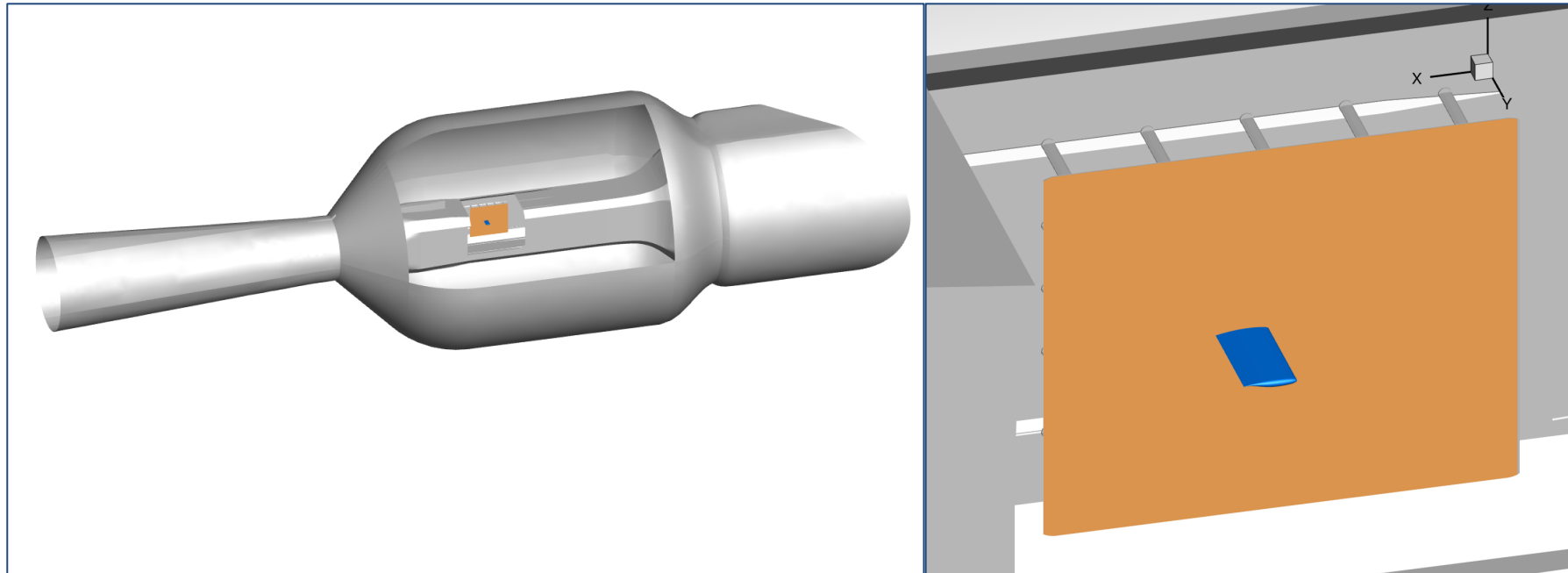- Roe scheme, Hvanalbada limiter, Second order in time

3D Analysis Approach (1)

Fixed Mesh	Coarse	Medium	Fine	XFine
Size (nodes)	3M	9M	27M	99M
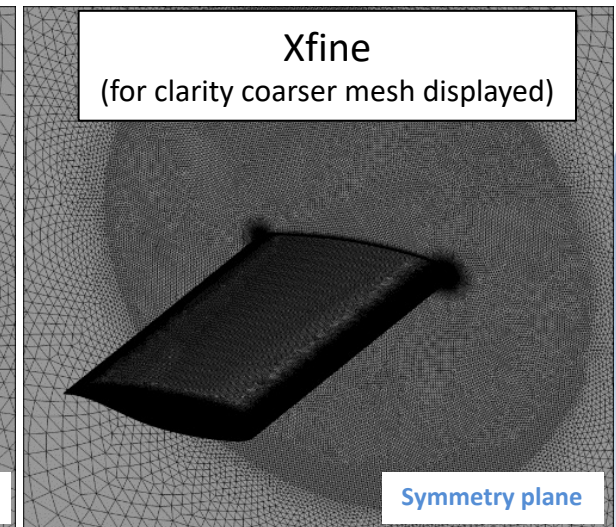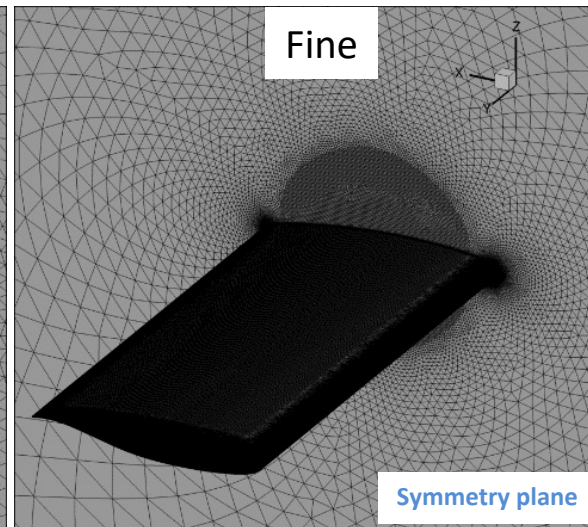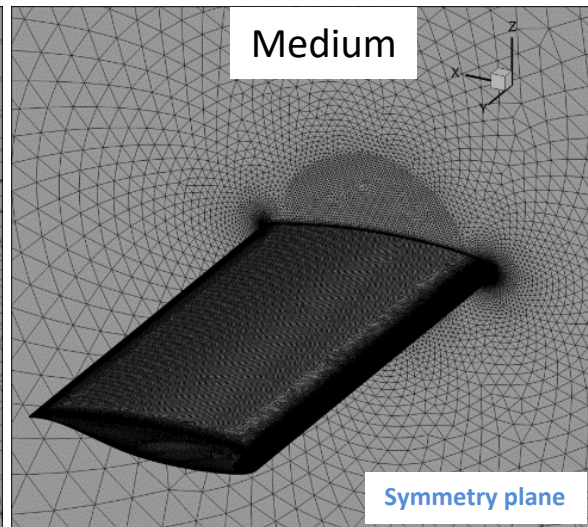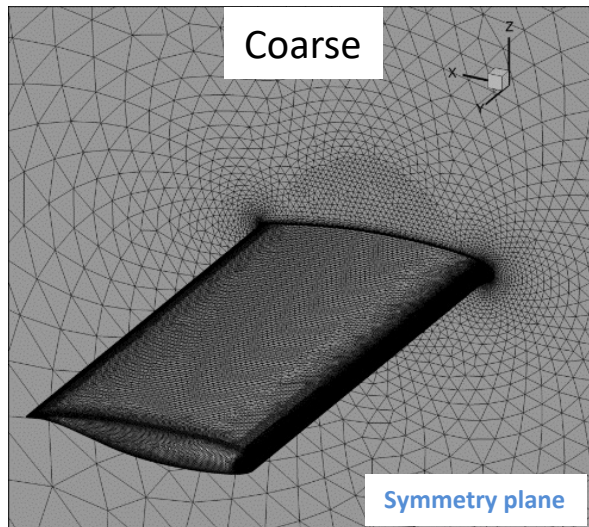
3D Analysis Approach (2)

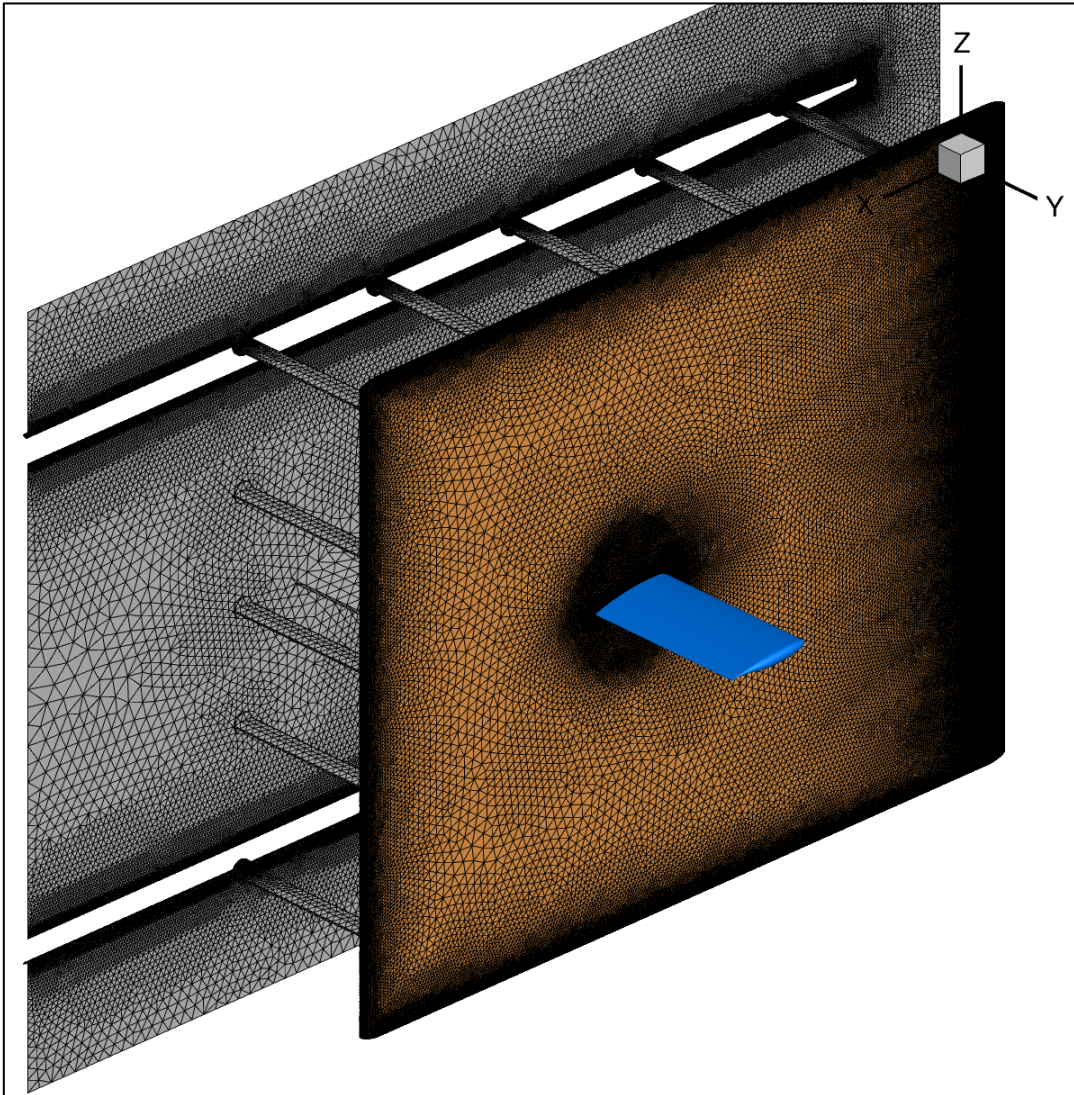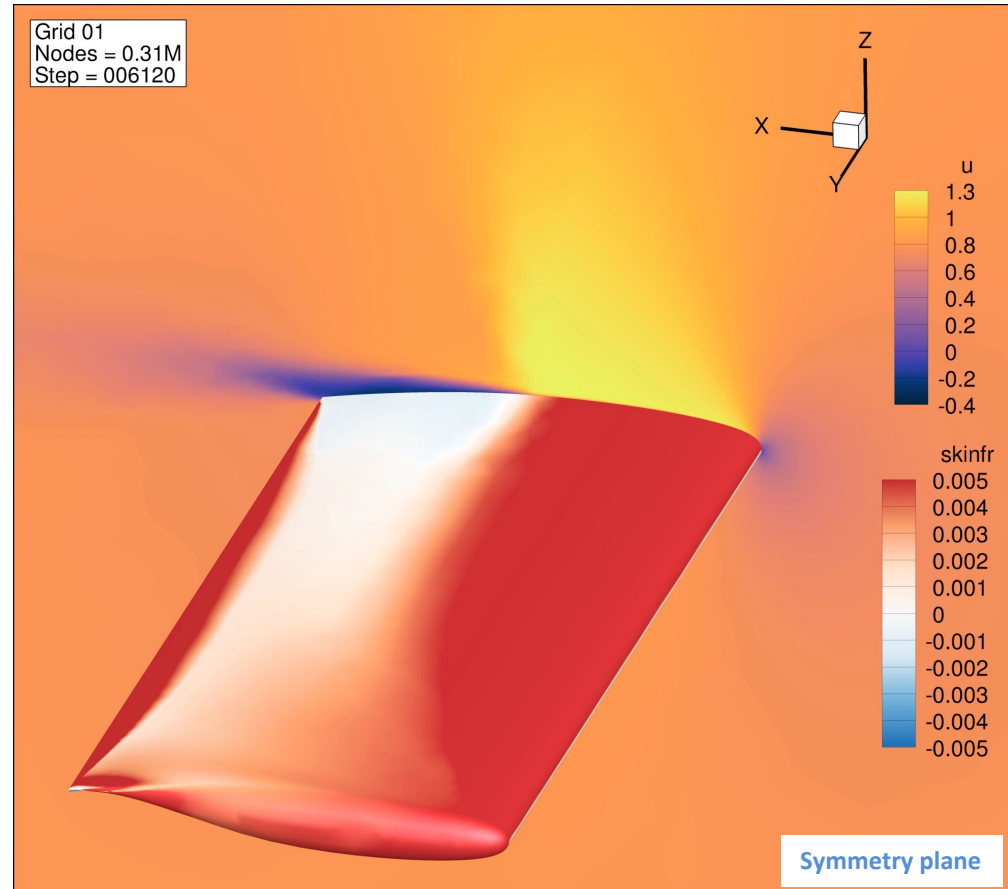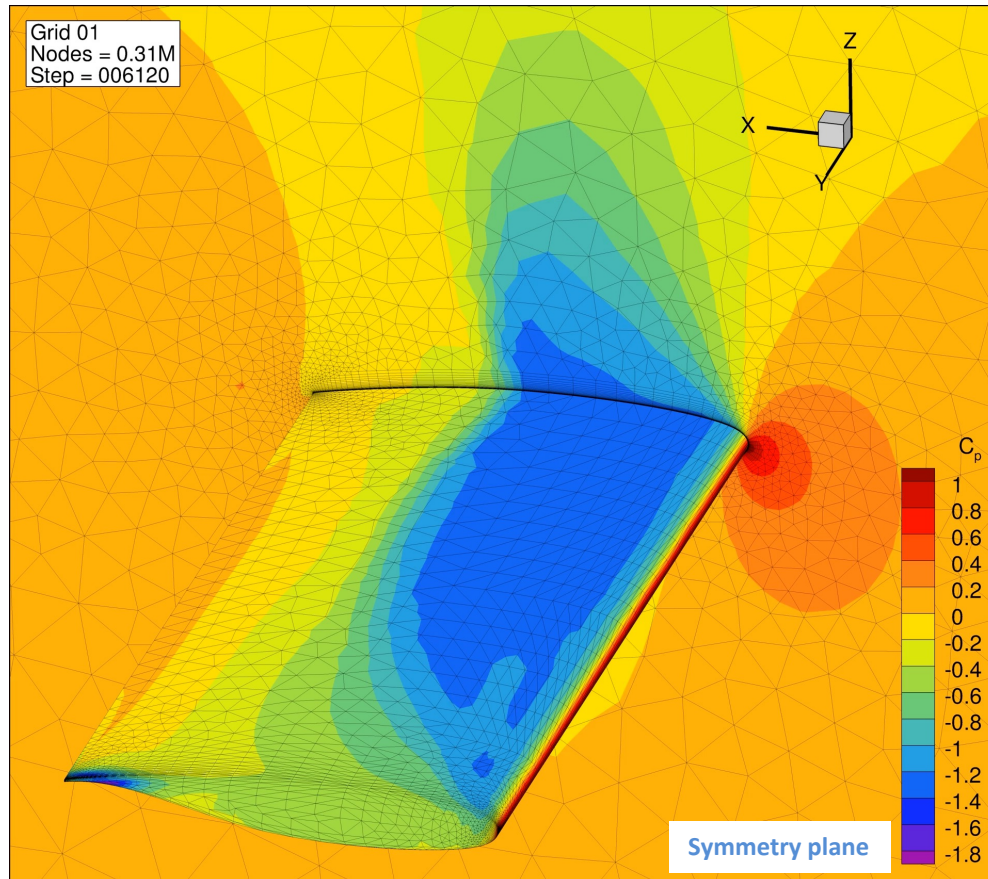| Fixed Mesh	Coarse	Medium
Size (nodes)	109M	161M

BSCW as installed in TDT

3D Analysis Approach (2)
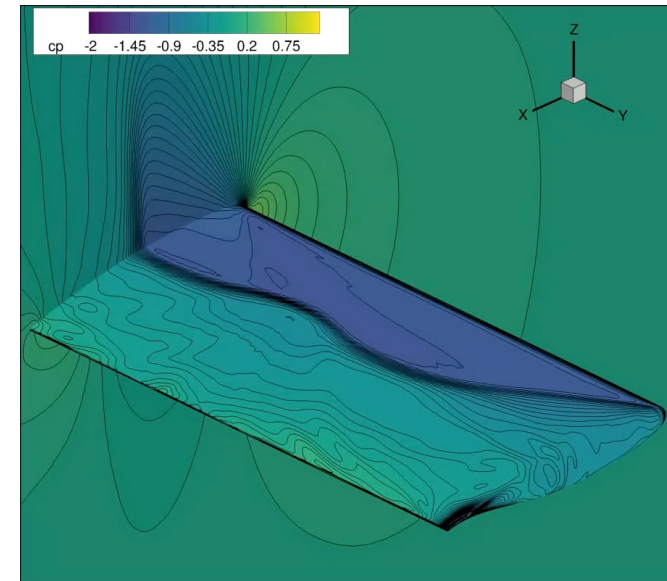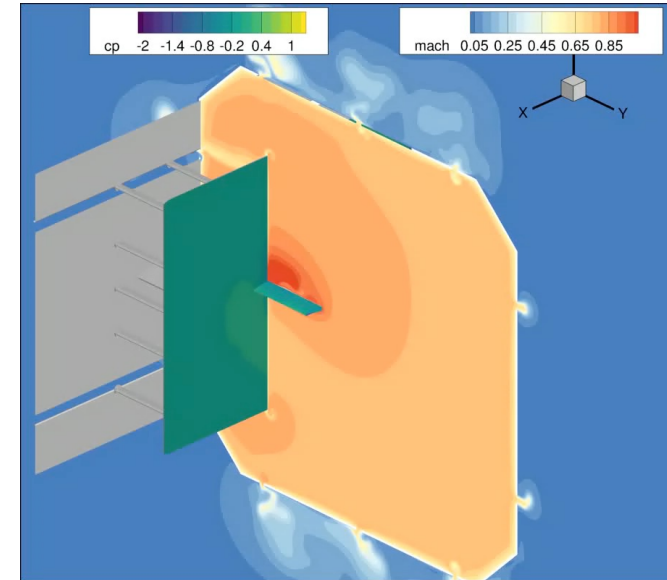
3D Analysis Approach (3)

- Mesh Adaption via Point Sources
- Mesh adapted using interpolation[1] based error estimation.
  - Error is accumulated over time to capture shock movement.

[1]Zienkiewicz, O.C. and Zhu, J.Z. (1987) A Simple Error Estimator and Adaptive Procedure for Practical Engineering Analysis. International Journal for Numerical Methods in Engineering, 24, 337-357.

Results
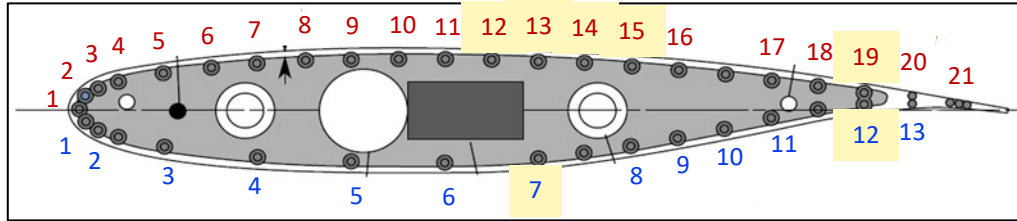
	Solution Method	Turbulence Model	Mesh Type	Mesh Size	Time Step
FUN3D	DDES	SA	Unstructured	27M	2.10E-06
FUN3d Large dt	DDES	SA	Unstructured	27M	2.10E-05
FUN3D Mesh Adapt	DDES	SA	Unstructured	60M	6.00E-06

Table 3. Pressure orifice locations, x/c, at 60% span

Upper		Lower	
Transducer #	x/c	Transducer #	x/c
1	0	1	0.012
2	0.009	2	0.027
3	0.023	3	0.103
4	0.049	4	0.203
5	0.099	5	0.303
6	0.149	6	0.403
7	0.198	7	0.503
8	0.249	8	0.602
9	0.298	9	0.652
10	0.348	10	0.702
11	0.398	11	0.752
12	0.448	12	0.851
13	0.498	13	0.901
14	0.542		
15	0.598		
16	0.648		
17	0.749		
18	0.799		
19	0.849		
20	0.899		
21	0.95		
22	1		

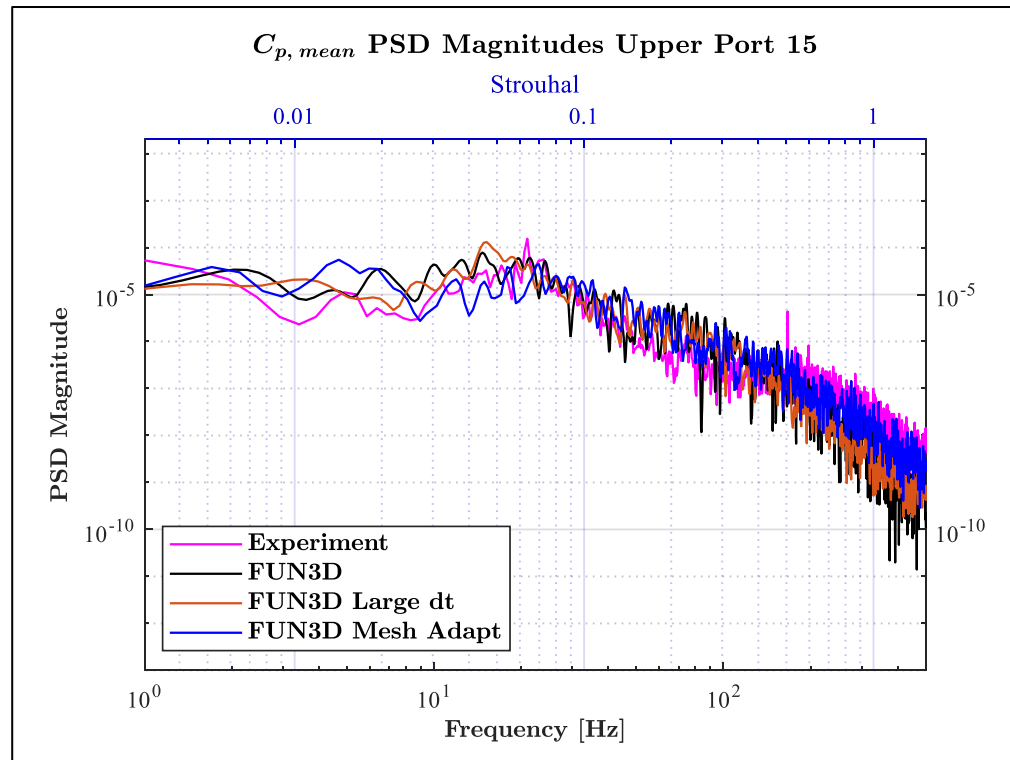## Results – PSD, C$_p$
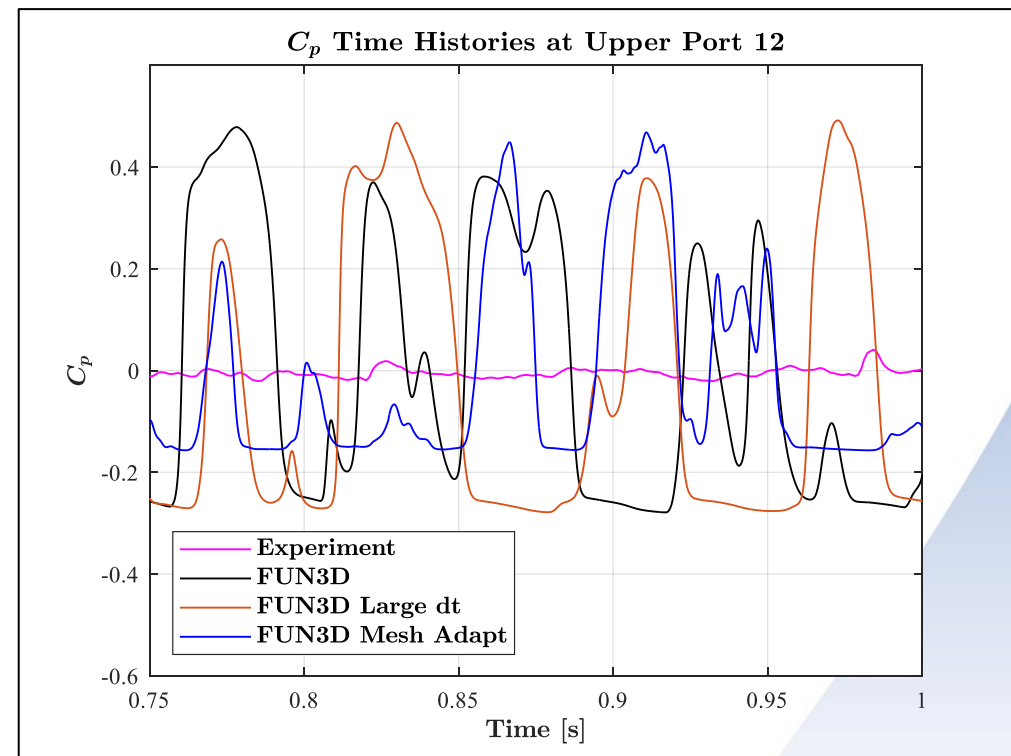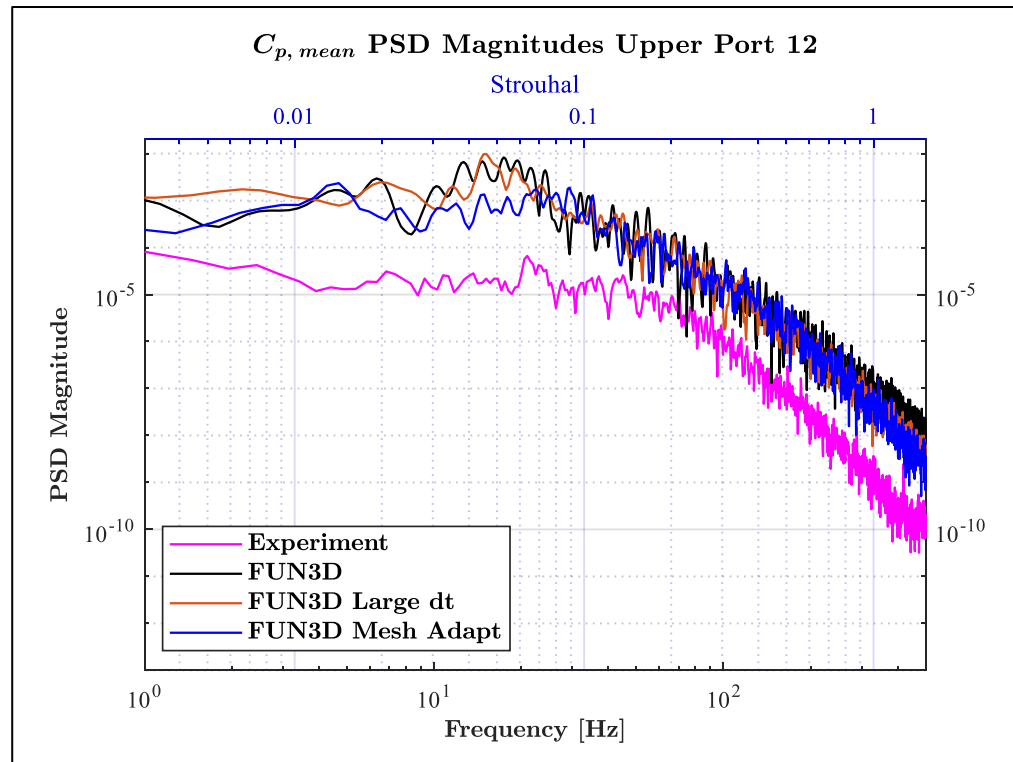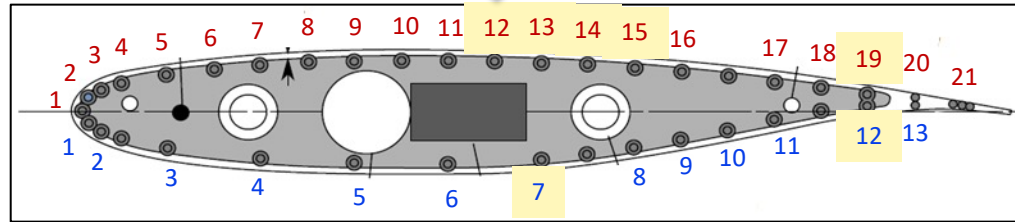
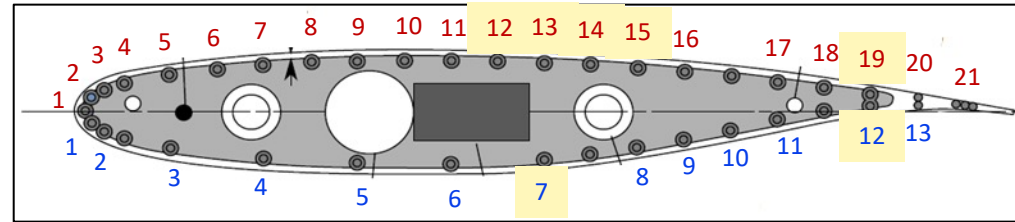# Results – PSD, C_p
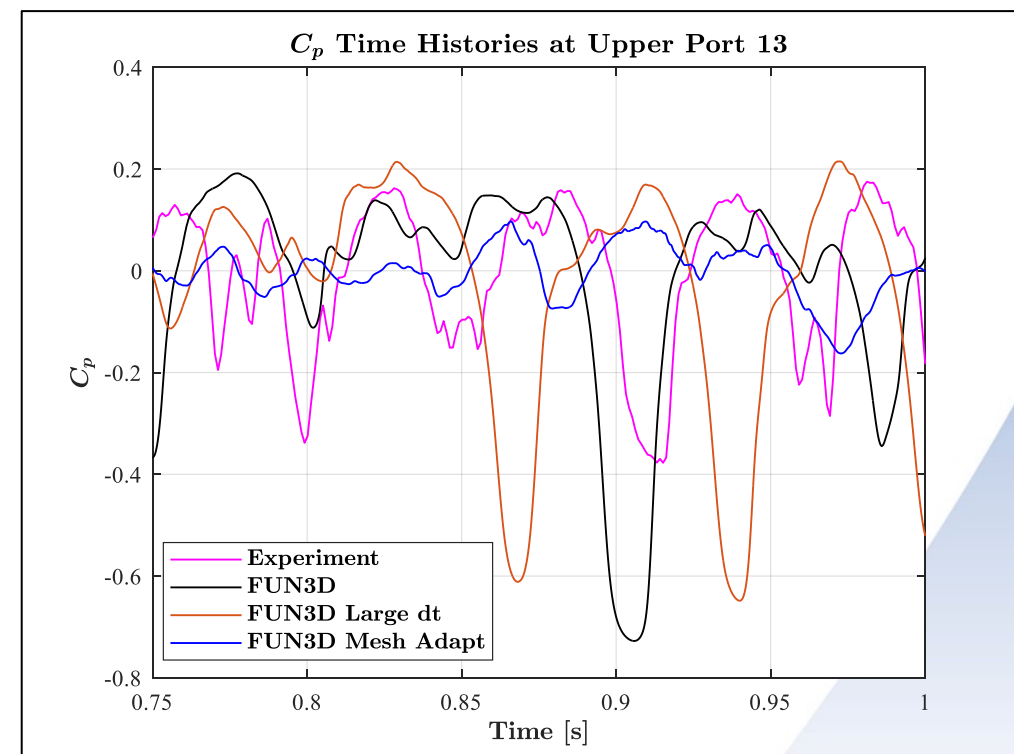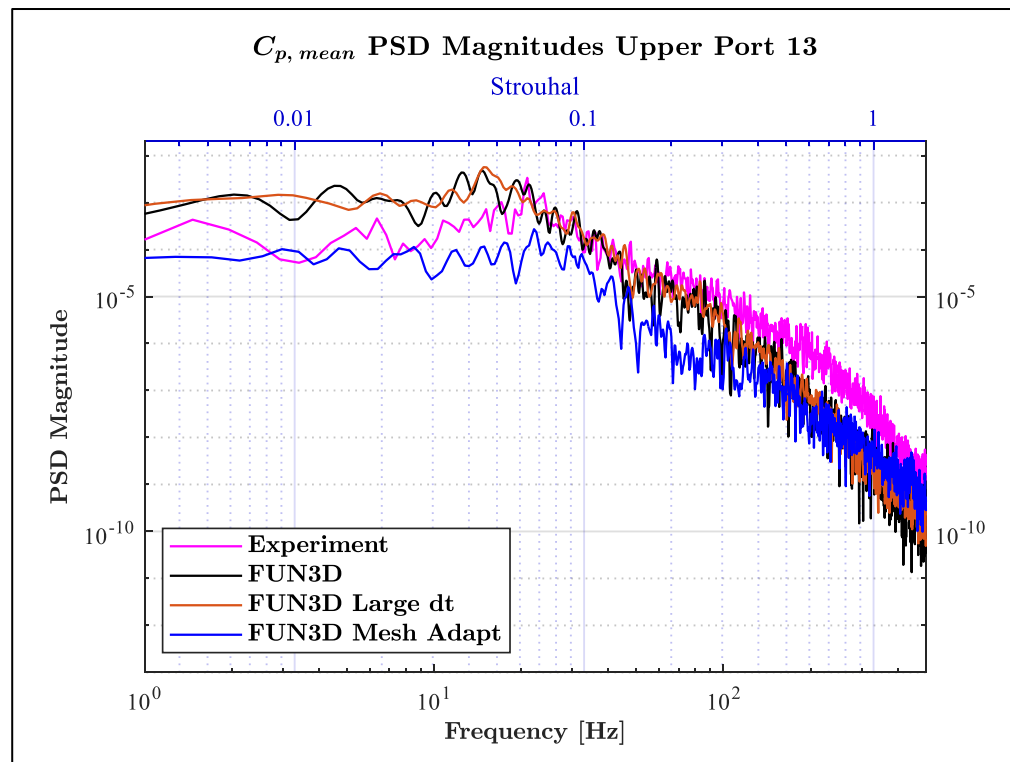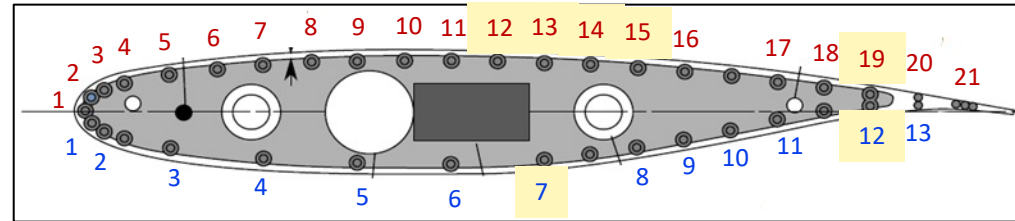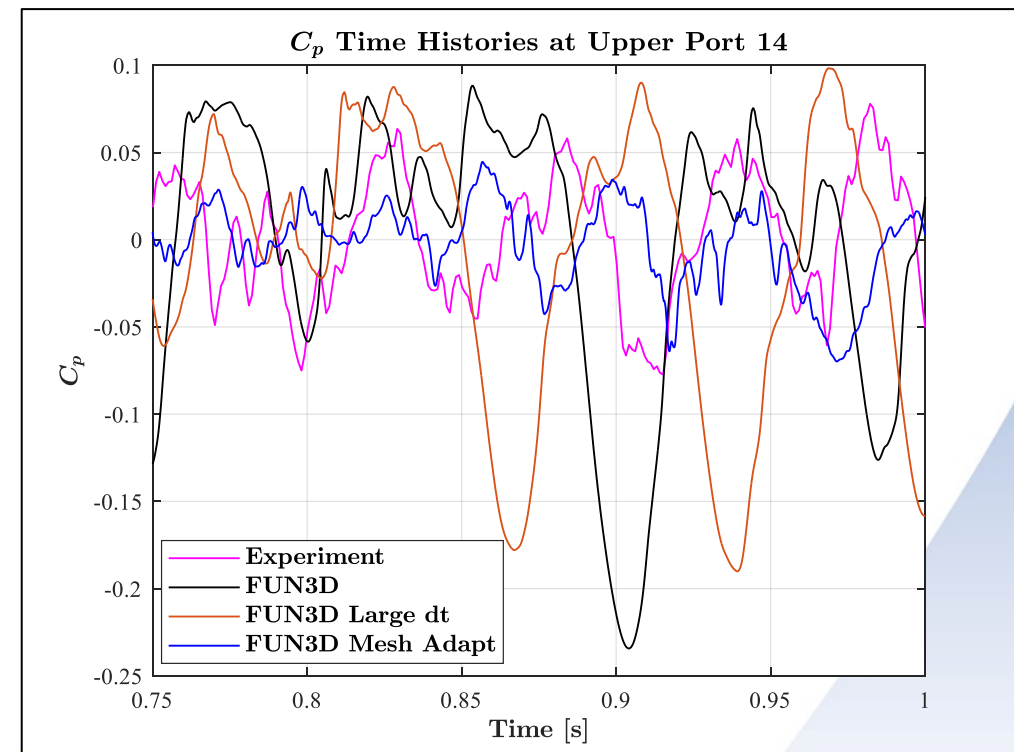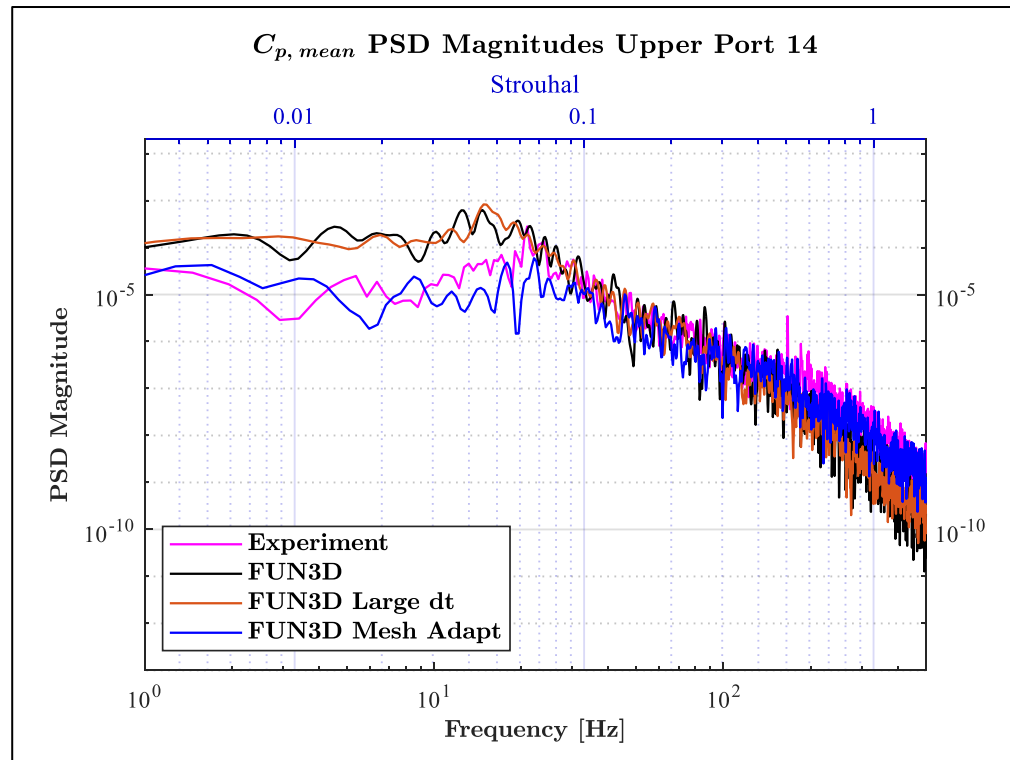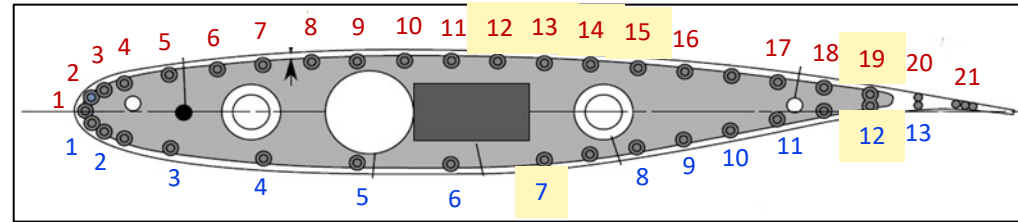
Results – PSD, C$_p$
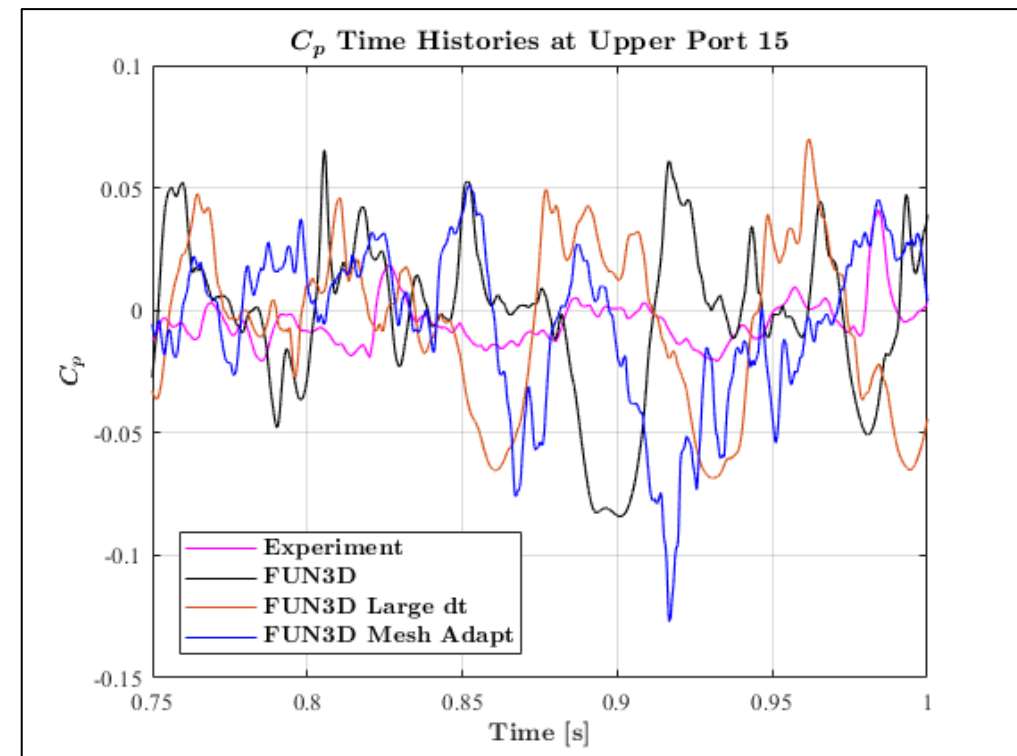
Results – PSD, C_p
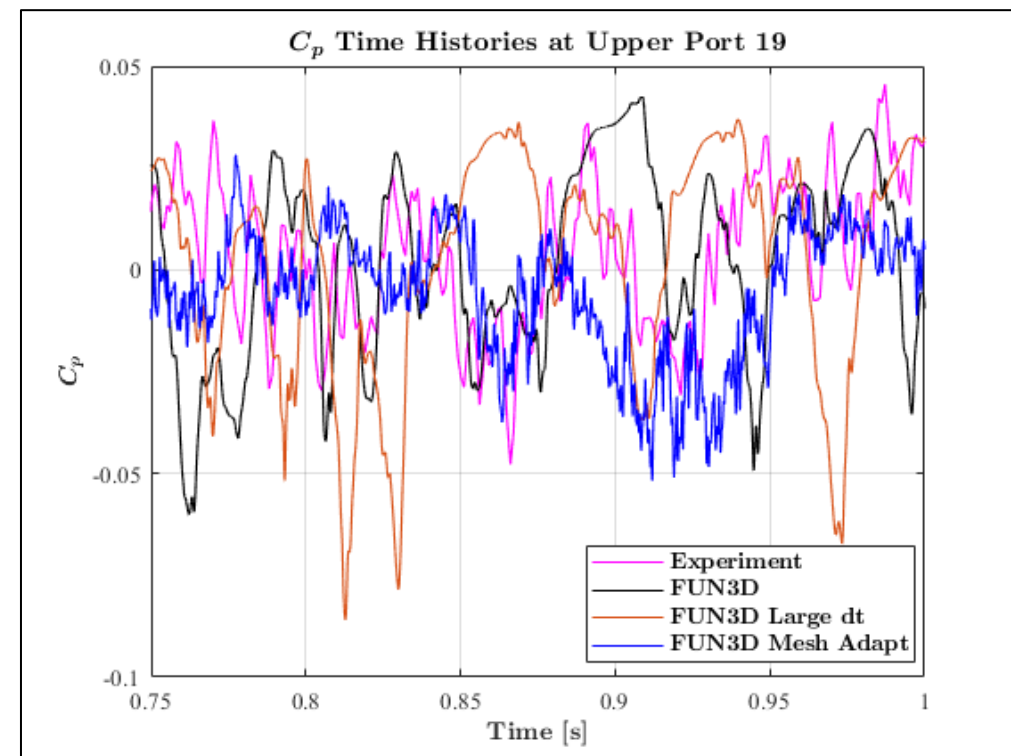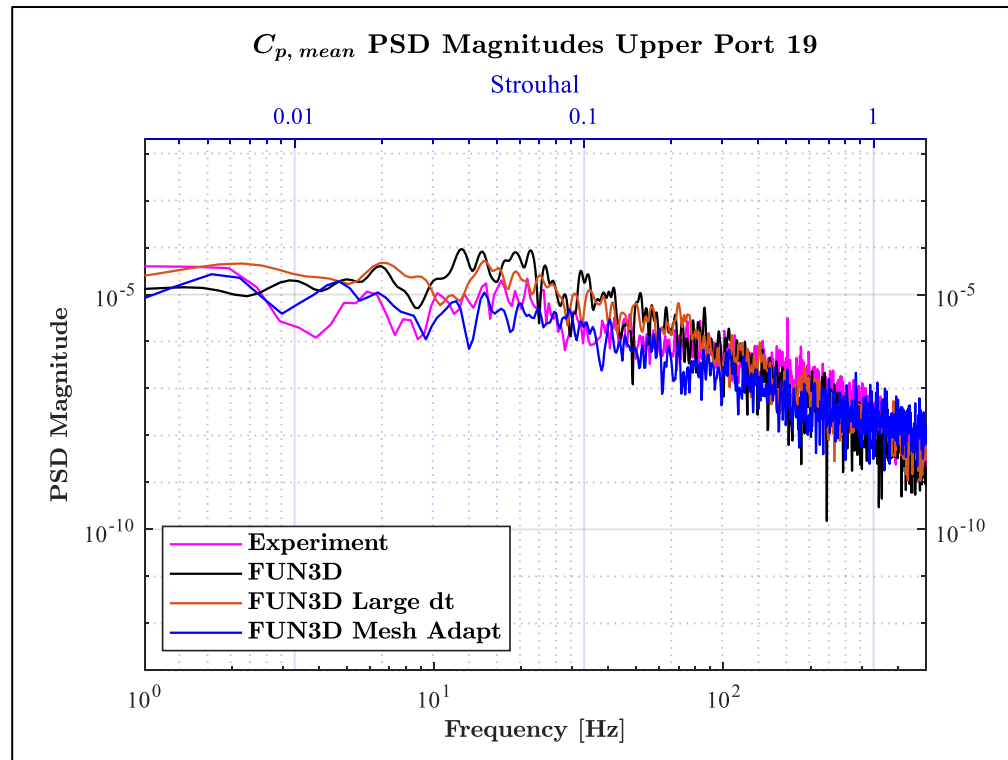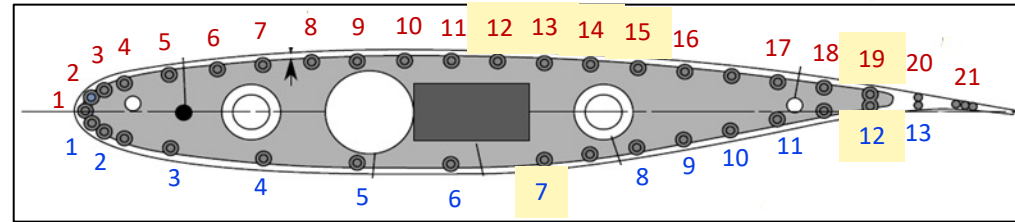
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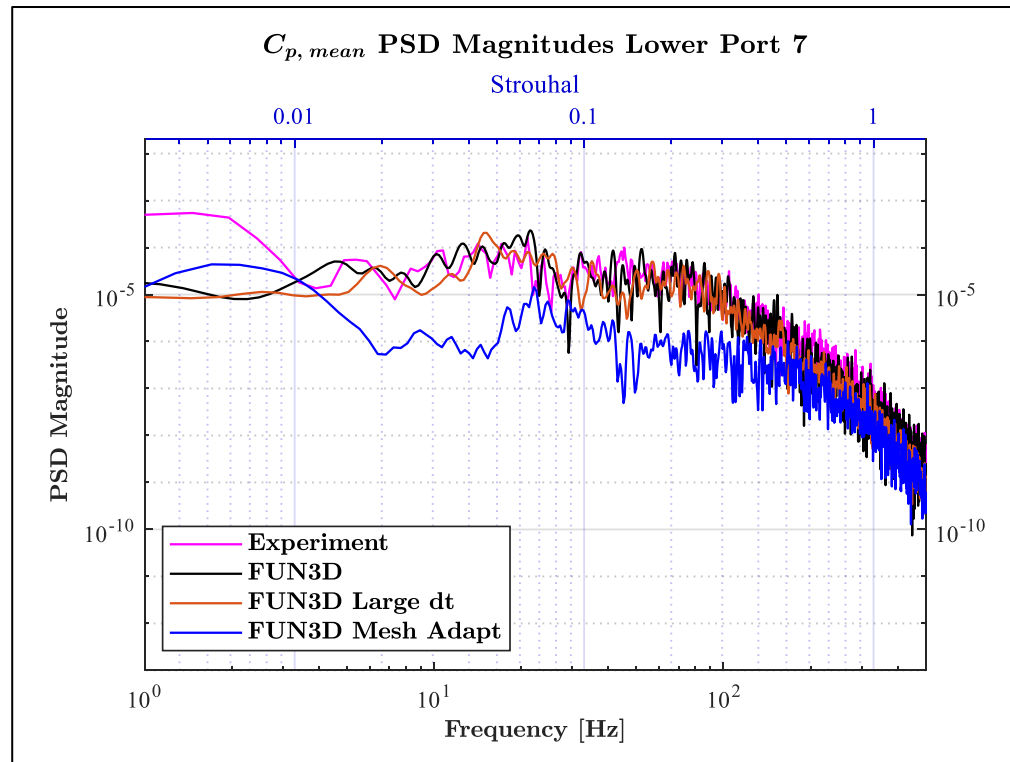
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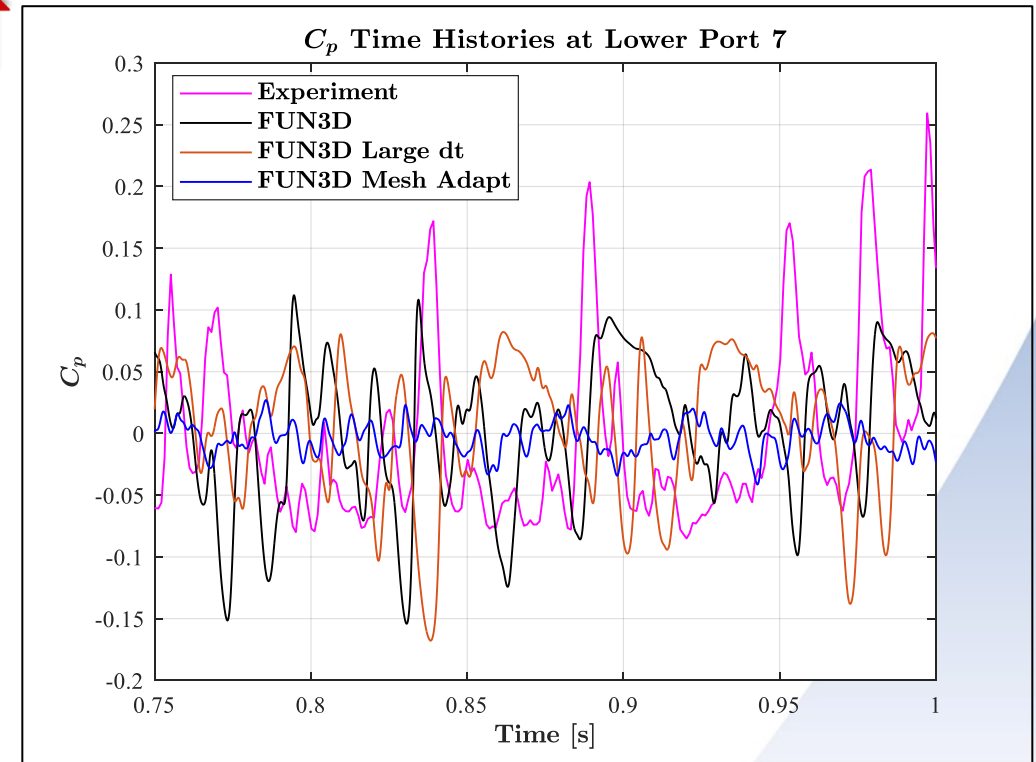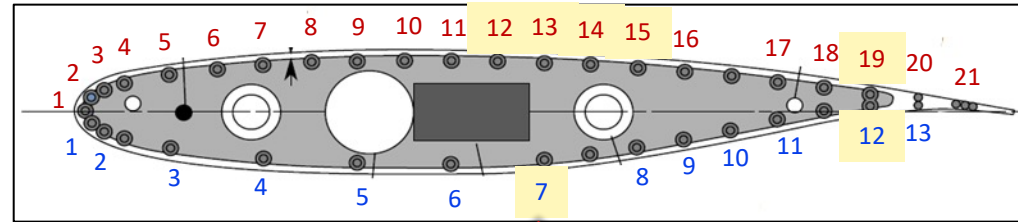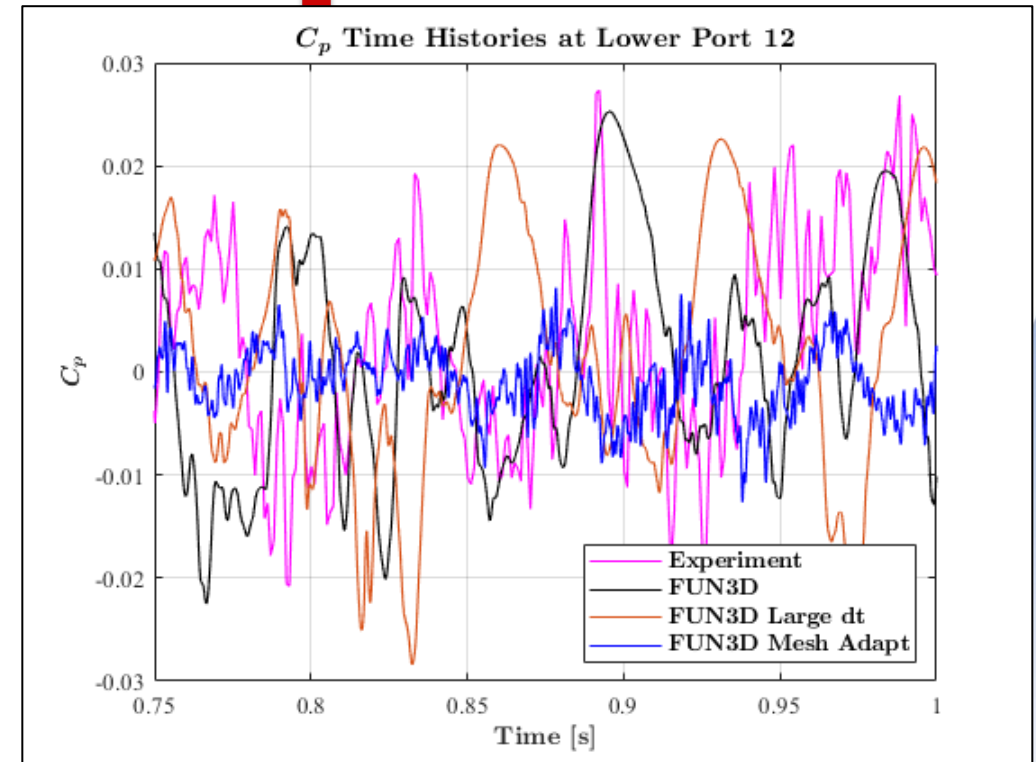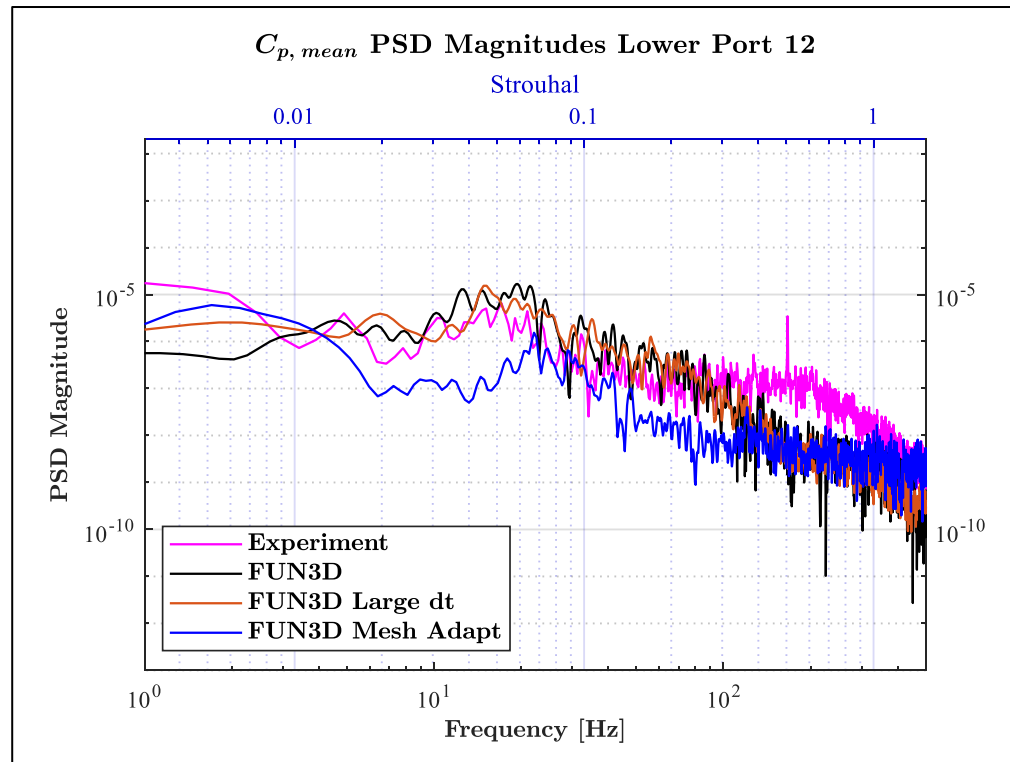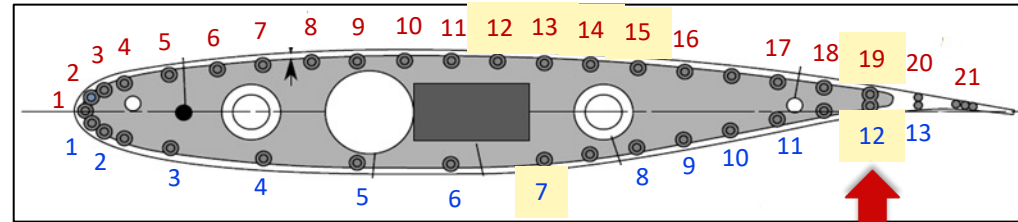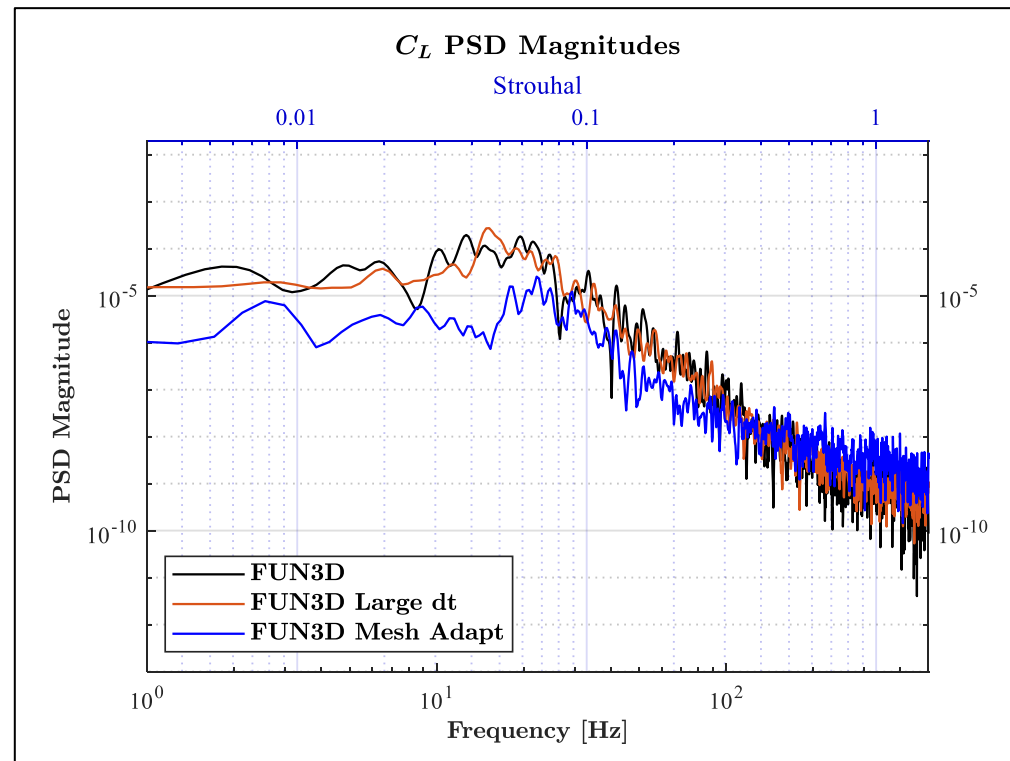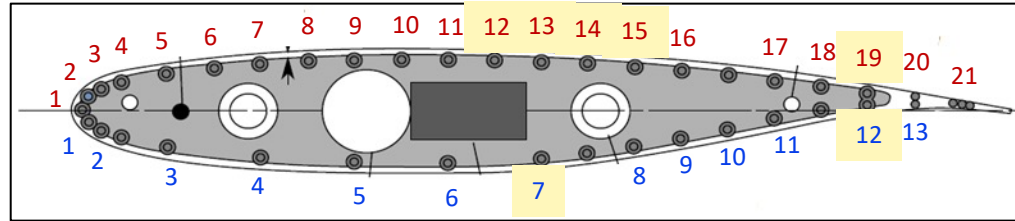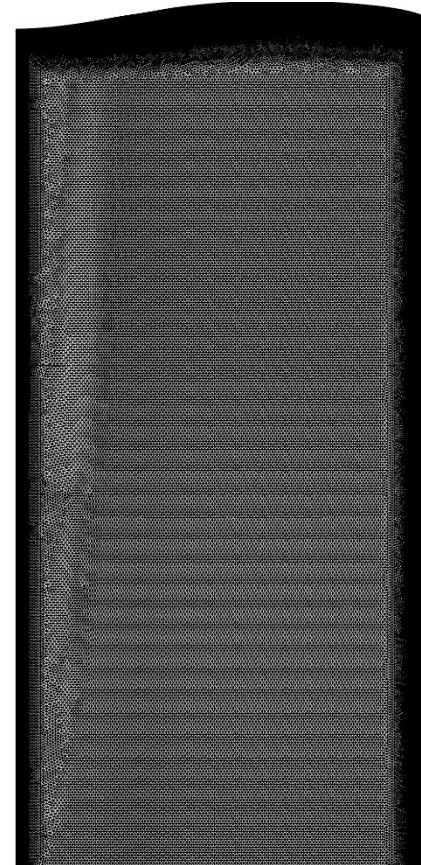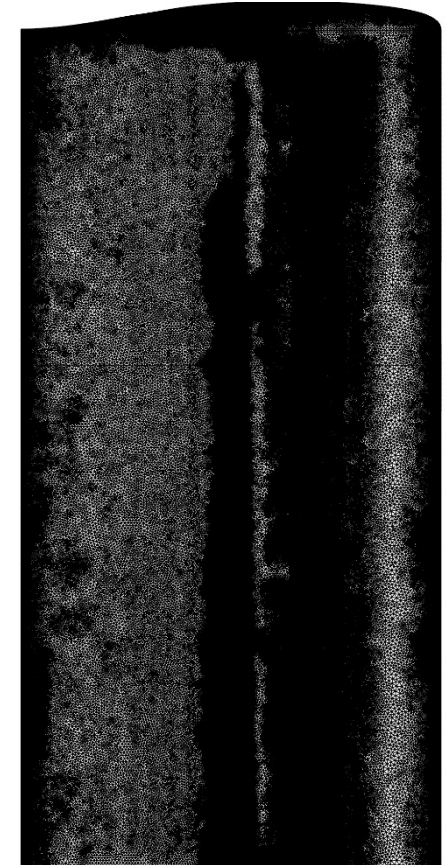## Results – PSD C_L

Results - Grids

FUN3D Upper Surface

FUN3D Mesh Adaptation
Upper surface

FUN3D Lower Surface
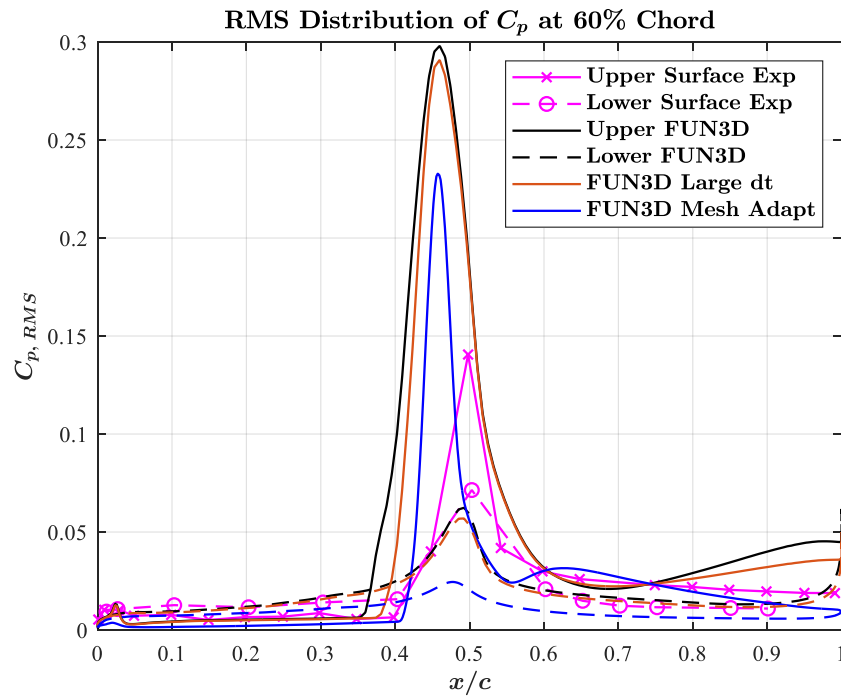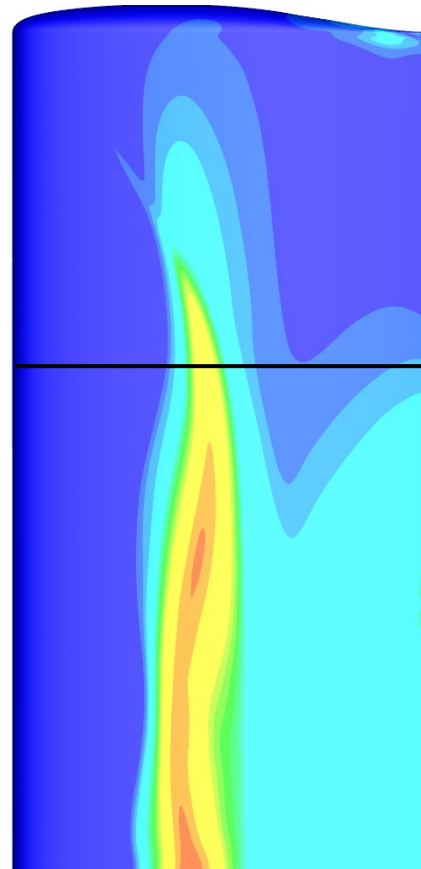
FUN3D Mesh Adaptation
Lower Surface

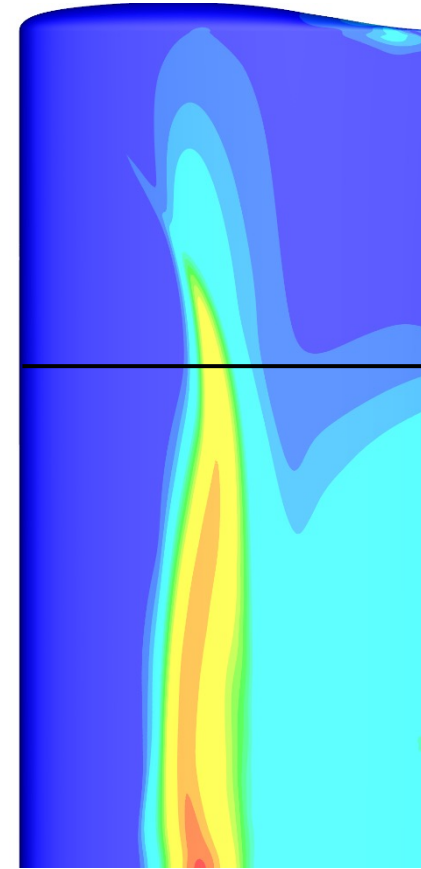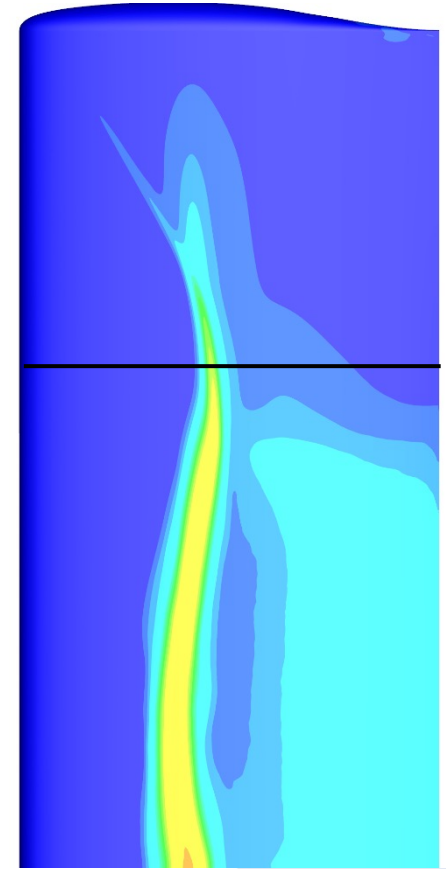## Results – RMS
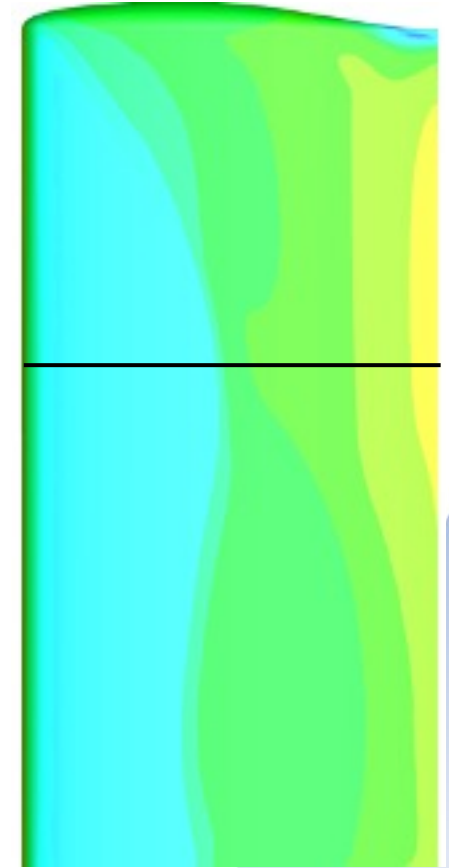
Results - C$_p$

FUN3D

FUN3D
Large dt

FUN3D Mesh
Adaptation

C_p Mean Results of FUN3D and Experimental

BSCW Shock-Buffet Analysis at Mach 0.8, AoA = 5°, q = 170 psf
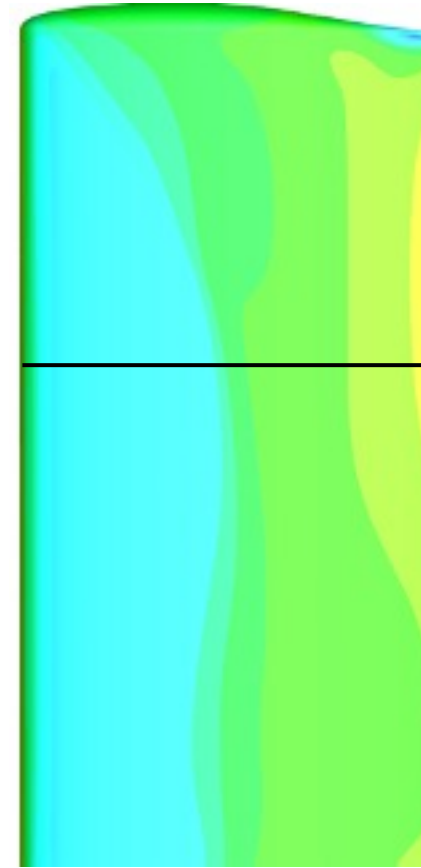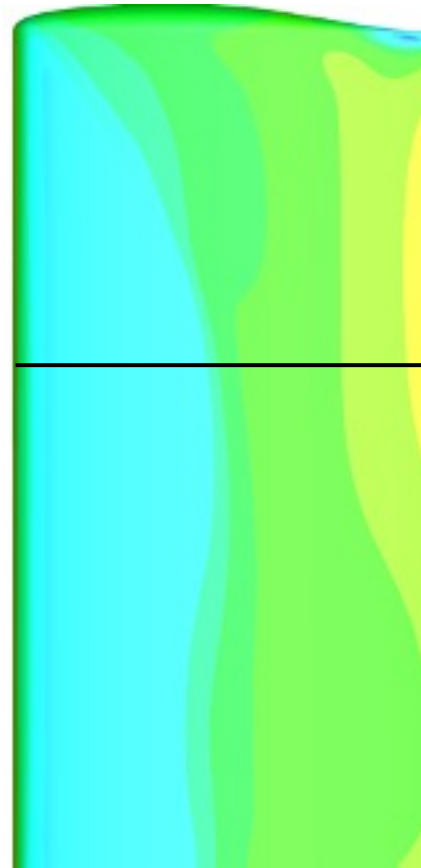
Results – Skin Friction

FUN3D Mesh Adaptation

FUN3D